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Title: SPATIAL VARIABILITY OF MEAN FLOW AND TURBULENCE FIELDS IN STREET CANYONS

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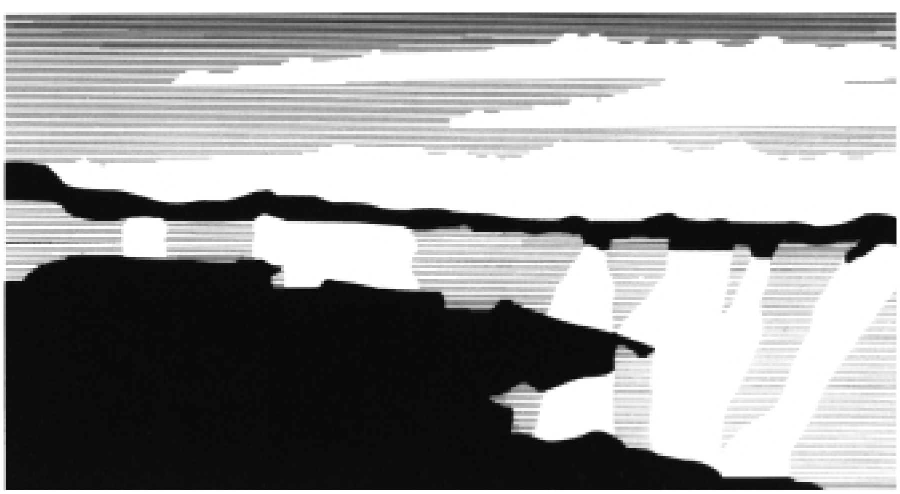

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2.5 SPATIAL VARIABILITY OF MEAN FLOW AND TURBULENCE FIELDS IN STREET CANYONS

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1. INTRODUCTION

Air pollution episodes in cities are often related to emissions from traffic. These emissions occur near the ground, and dispersion of the exhaust gases is highly affected by the complex flow phenomena inside the urban canopy. Applied dispersion models must be able to predict the flow patterns observed inside and above the street canyons. During the last few years, the flow and dispersion characteristics in street canyons were investigated in several wind tunnel studies. Two major questions are nevertheless left open: (i) how strong is the influence of the particular wind tunnel setup on the observed characteristics of flow in street canyons, and (ii) to what extent can these characteristics can be parameterized?

In the present paper, we undertake a comparison of flow parameters measured in three different wind tunnel models of street canyons with idealized geometry and in a detailed model of a real street canyon surrounded by an urban canopy. In all experiments considered, mean values and turbulent statistics of all three velocity components were derived from high-resolution flow measurements. We discuss the spatial variability of the flow and turbulence fields inside and above the canyons, and the influence of urban canopy irregularities on the properties of spatially averaged flow profiles.

2. EXPERIMENTAL SETUP

The wind tunnel studies chosen for comparison and the corresponding references are presented in Table 1. The aspect (height-to-width) ratios of the IC-UKA and IC-EPA idealized canyons (IC) were 1. The approach flow was perpendicular to the axis of the canyon and mean and turbulent velocities were measured in its central plane (*y*=0cm). For the RC-UKA study (Real Canyon), a detailed model of the central part of Nantes, France was constructed. Vertical velocity profiles were measured at several positions inside the model. The profile locations were chosen to trace the horizontal variability of the flow inside and above a street canyon (Rue de Strasbourg) oriented perpendicular to the wind direction.

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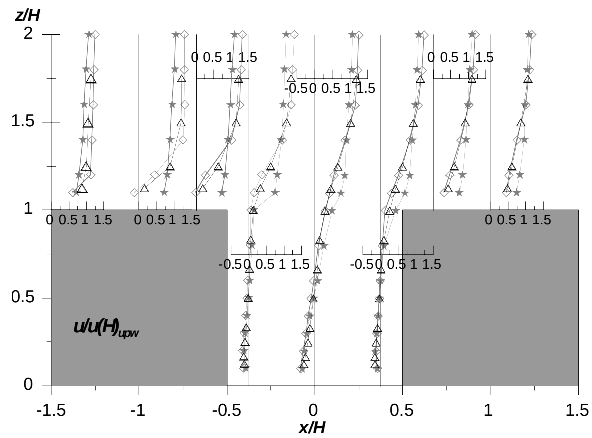

Fig. 1: Profiles of the *u*-velocity component. Triangles: IC-UKA, *L*=120 cm. Diamonds: IC-EPA, first canyon. Stars: IC-EPA, sixth canyon.

3. RESULTS

A comparison of IC-UKA and IC-EPA mean velocity and turbulence kinetic energy (TKE) profiles is presented in Figs. 1-2. As velocity scale, the value $u(H)_{upw}$ at the level of the building height in the undisturbed approach flow is used.

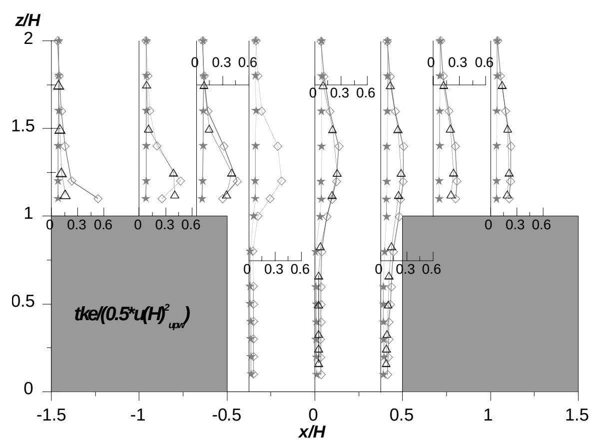

Fig. 2: Profiles of the TKE (symbols as in Fig. 1).

The IC-UKA results agree well with the data for the first canyon of the IC-EPA array. In both cases, the flow separation at the upwind building edge results in strong mean velocity gradients and high TKE values in a shear region above the roofs, where the largest differences are observed between velocity fields for the cases of the first and sixth IC-EPA canyons. The

Table 1: Description of wind-tunnel studies employed in the presented comparison

Study	Building configuration	Measurement technique	Wind tunnel	References
IC-UKA	one idealized street canyon in non-urban terrain, flat or slanted roofs	Laser Doppler anemometer	Neutral boundary layer wind tunnel, University of Karlsruhe, Germany	Kastner-Klein (1999)
RC-UKA	detailed model of an inner-city area in Nantes, France	Laser Doppler anemometer		Kastner-Klein et al. (2000)
IC-EPA	array of six idealized street canyons, flat roofs	Pulsed wire anemometer	Wind tunnel of the U.S. EPA Fluid Modeling Facility	Brown et al. (2000)

velocity field in the latter case corresponds to the skimming-flow type adjusted to the underlying surface. At roof level, the flow velocity upgrades rapidly to the boundary layer value. The TKE values in this case are small and do not significantly vary with height.

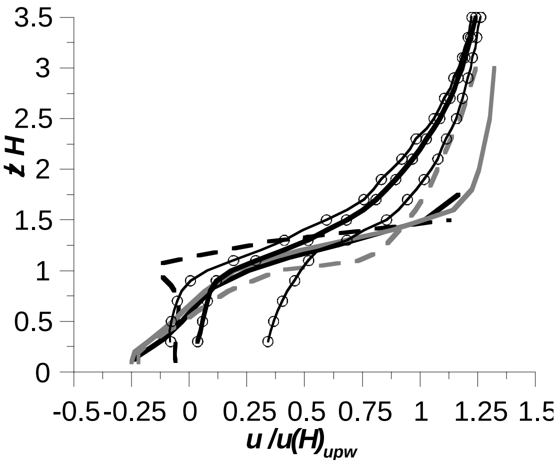

Fig. 3: Averaged profiles of the *u*-velocity component. Black lines: IC-UKA, solid for flat roofs and dashed for slanted upwind roof. Gray lines: IC-EPA, solid for first canyon and dashed for sixth canyon. Circles: RC-UKA (thick line - mean; thin lines - lowest/highest values).

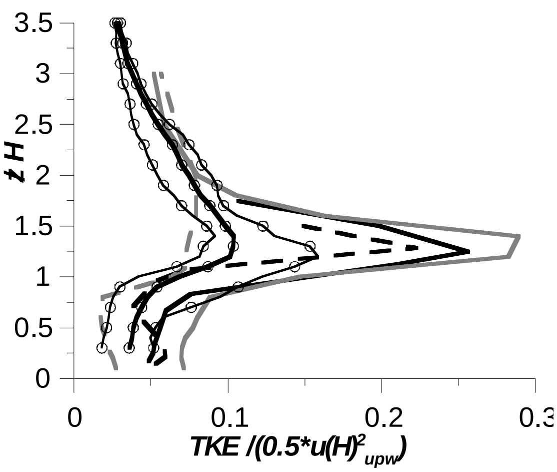

Fig. 4: Averaged turbulence kinetic energy profiles (symbols as in Fig. 3).

Spatially averaged profiles of mean velocity and turbulence kinetic energy are presented in Figs. 3-4. The results of the RC-UKA study demonstrate that flow characteristics above a realistic irregular urban canopy are generally similar to the ones observed in the case of idealized regular building arrays. RC-UKA building pattern irregularities lead to more pronounced TKE maxima in the shear region above the roof level compared with the related TKE value in the case of the sixth IC-EPA canyon. The IC-UKA study has shown that the building roof shape has remarkably strong influence on mean flow characteristics inside the canyon.

4. SUMMARY

We have found good agreement between the flow characteristics inside and above idealized street canyons of similar geometry studied in the two different tunnels. A vortex-type motion and associated reverse flow in the lower part of the canyon have been observed in isolated as well as in urban-type idealized canyons with flat roofs. In canyons formed by slanted-roof buildings, this motion has been much weaker and less stable. The in-canyon vortex has been also observed inside a street canyon within a detailed model of a real urban canopy cluster. Maxima in the TKE profiles above the building roofs have been associated with situations in which the canyon is close to a change in the underlying surface structure. The largest energy maxima have been found above isolated two-dimensional canyons.

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5. REFERENCES

Brown, M.J., Lawson, R.E., Decroix, D.S., Lee, R.L., 2000: Mean flow and turbulence measurements around a 2-D array of buildings in a wind tunnel. 11th Conf. on Appl. of Air Poll. Met., Long Beach, CA, Jan. 2000.

Kastner-Klein, P., Rotach, M. W., Fedorovich, E., 2000: Experimental study on mean flow and turbulence characteristics in an urban roughness sublayer, 14th Symp. on Bound. Layers and Turb., Aspen, CO, August, 7th-11th.

Kastner-Klein, P., 1999: Experimentelle Untersuchung der strömungsmechanischen Transportvorgänge in Straßenschluchten. Dissertation, Universität Karlsruhe, Germany.